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Applied physics across generations: Cultivating scientific curiosity through health and energy applications

Evelyn Pratami Sinaga[1]*, Rizki Budiman[1], Jonathan P. Satya[1], Grace V. Priskila[1], Josua T. Manik[1], E. H. Hasdeo[2]
[1]Department of Physics, Matana University, Indonesia
[2]Research Center for Quantum Physics, National Research and Innovation Agency, Indonesia

*) Corresponding Author (e-mail: evelyn.sinaga@matanauniversity.ac.id)

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Abstract

Physics is frequently regarded by students as an abstract and challenging subject, disconnected from everyday experience, which often results in low motivation and limited engagement across different levels of science education. As a continuation of our previous community service program on medical physics education, this second initiative extends the same approach to students at Jaya Plus Montessori School. The program aims to demonstrate that physics is not merely theoretical but plays a vital role in real-world applications, particularly in medicine, including radiology, MRI, CT scans, and radiation therapy for cancer treatment. This study employed a one-group pretest- posttest design conducted through a collaboration between Matana University and the school, involving high school students. The workshop combines a scientific talk on medical physics applications, a session on quantum physics and material science presented by a guest speaker from the National Research and Innovation Agency (BRIN), and hands-on physics demonstrations to make learning both contextual and engaging. Students are also introduced to career pathways in medical physics, such as medical physicist, radiographer, radiation therapist, and biomedical engineer, which are often overlooked in favor of more familiar healthcare professions. Pre- and post-tests are used to evaluate changes in students' understanding and interest before and after the activity.

Keywords: Medical Physics, Science Education, Healthcare Technology, Student Motivation, Interdisciplinary Learning.

Abstrak

Fisika sering dianggap oleh siswa sebagai mata pelajaran yang abstrak dan sulit sehingga motivasi serta keterlibatan mereka dalam pembelajaran sains cenderung rendah. Sebagai kelanjutan program pengabdian kepada masyarakat sebelumnya tentang edukasi fisika medis, kegiatan ini memperluas pendekatan tersebut kepada siswa Jaya Plus Montessori School. Program bertujuan menunjukkan bahwa fisika memiliki peran penting dalam kehidupan nyata, khususnya di bidang kesehatan, seperti radiologi, *magnetic resonance imaging* (MRI), *computed tomography* (CT scan), dan terapi radiasi untuk pengobatan kanker Melalui kolaborasi Universitas Matana dan sekolah, kegiatan meliputi seminar fisika medis, sesi fisika kuantum dan ilmu material oleh narasumber dari Badan Riset dan Inovasi Nasional (BRIN), serta demonstrasi eksperimen fisika yang interaktif dan kontekstual. Siswa juga diperkenalkan pada berbagai profesi di bidang fisika medis. Efektivitas program dievaluasi melalui pre-test dan post-test untuk mengukur perubahan pemahaman dan minat siswa terhadap fisika.

Kata kunci: Fisika Medis, Pendidikan Sains, Teknologi Kesehatan, Motivasi Belajar, Pembelajaran Interdisipliner.

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1. Introduction

Physics is frequently regarded by students as an abstract and challenging subject, disconnected from everyday experience, which often results in low motivation and limited engagement across different levels of science education (Hake, 1998)(Keller et al., 2017)(Osborne et al., 2003). This perception is reinforced by conventional instruction that emphasizes memorizing formulas and applying them to standardized problems (Freeman et al., 2014), engaging only the lower levels of Bloom's Taxonomy (remembering, understanding, applying) while rarely inviting students to analyze real systems, evaluate solutions, or create something new using physics principles (C6, the highest cognitive level; Krathwohl, 2002). Figure 1 illustrates how each level of Bloom's Taxonomy can be mapped onto concrete examples of physics learning, from basic facts and units (remember) to designing original solutions, such as a solar-powered device (*create*). Yet physics is, at its core, a generative discipline suited to this kind of higher-order thinking: a science of explaining, predicting, and designing solutions to real problems, from diagnosing disease to harnessing renewable energy.

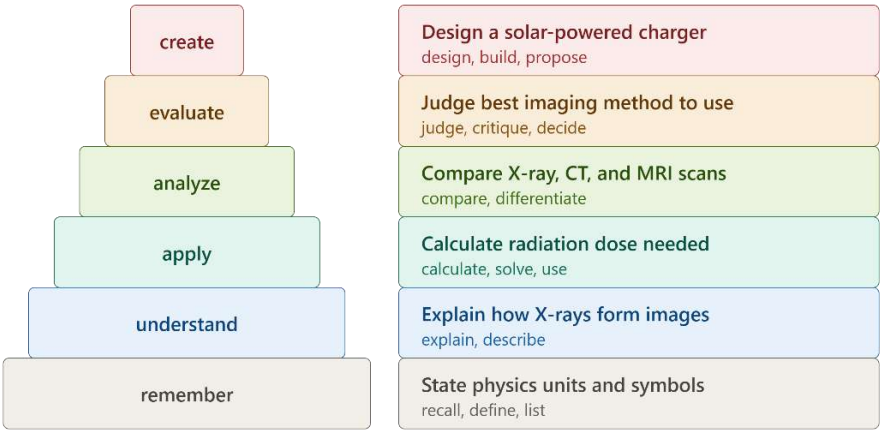


Figure 1. Bloom's Taxonomy applied to physics education.

The pyramid illustrates the six cognitive levels of Bloom's Taxonomy (Anderson & Krathwohl, 2001), each paired with a physics-specific learning example spanning medical physics and renewable energy applications, from recalling basic facts (*remember*) to designing original solutions (*create*). Adapted from Vanderbilt University Center for Teaching.

Medical physics offers a compelling example of this relevance for secondary school students. As a discipline that merges physics with technology for healthcare applications (Bushberg et al., 2012), it underlies diagnostic tools such as X-ray, CT, and MRI (McRobbie et al., 2017), as well as radiation therapy for cancer treatment (Khan & Gibbons, 2014). Careers in this field extend well beyond physicians to include medical physicists, radiologic technologists, radiation therapists, and biomedical engineers professions still largely unfamiliar to Indonesian students despite growing demand following the Indonesia's Ministry of Health Regulation No. 83/2015 on Medical Physics Service Standards (*Peraturan Menteri Kesehatan Republik Indonesia Nomor 83 Tahun 2015 tentang Standar Pelayanan Fisika Medik*), which requires certified medical physicists at healthcare facilities providing diagnostic/interventional

radiology, radiotherapy, and nuclear medicine services (Kementerian Kesehatan Republik Indonesia, 2015; International Atomic Energy Agency, 2013).

For younger learners, energy and sustainability provide an equally accessible entry point into physics. Concepts such as renewable energy and technological innovation align naturally with inquiry-based, transdisciplinary frameworks, the "How the World Works" theme (International Baccalaureate Organization, n.d.), allowing primary students to engage concretely with physics through hands-on exploration rather than abstract formalism — building early curiosity and confidence that can carry into later years of education (Hidi & Renninger, 2006; Tai et al., 2006).

As a continuation of our previous community service program on medical physics education (Sinaga et al., 2026), this initiative extends the same underlying philosophy using real-world applications to make physics relevant and engaging across two educational settings and age groups: a medical physics workshop for high school students at Jaya Plus Montessori School, and an energy and technology focused session for Grade 3 and 4 students at Genesis Global Community School. Together, these programs reflect a shared belief that physics, when connected to problems students genuinely care about, becomes a source of curiosity and confidence rather than an abstract or intimidating subject.

2. Method

Overall design

This program was implemented as two separate sessions: a medical physics workshop held at Jaya Plus Montessori School on 14 July 2026 (08.00–12.00, involving approximately 20 high school students), and an energy and technology session held at Genesis Global Community School on 30 January 2026 (09.00–11.05, involving approximately 20 Grade 3 and Grade 4 students). The same set of physics demonstration tools was brought to both sessions, with each tool reframed to align with the learning objectives and developmental level of its audience: energy and everyday technology for primary students, and medical physics applications for high school students. We refer to this approach descriptively as a *dual-audience, single-toolkit design* a term we use here to describe the specific structure of this program, rather than an established pedagogical framework from the literature.

Rather than developing a separate demonstration set for each session, the team deliberately reused the same physical apparatus at both schools, pairing each tool with a different real-world application depending on the audience. This reuse was intentional: it allows students at both levels to see that a single physics principle (e.g., electromagnetism, light polarization, energy conversion) is not confined to one context, but underlies multiple, seemingly unrelated technologies. While we are not aware of this specific dual-purpose reframing of a shared demonstration toolkit being documented in our prior PKM reports in this series (Sinaga et al., 2026), we present this less as a claim of absolute novelty and more as a demonstration of how a single physics toolkit can be reapplied through contextual reframing for two different age

groups within an integrated community engagement program. The following demonstration tools were brought on-site to both schools:

Table 1. Shared demonstration toolkit: physics concepts framing at primary level Grade 3–4, Genesis Global Community School

Tool	Physics Concept	Learning Objective	Student Activity	Guiding Question	Curriculum Alignment
Solar panel wired to an LED lamp	Conversion of light energy into electrical energy	Students understand how renewable energy can generate electricity without a battery or wall outlet	Operating the solar panel and observing the lamp turn on	How can sunlight power a lamp without a cable to a wall outlet?	IB PYP Grade 4 — "How the World Works": renewable/sustainable energy
Polarizing filter sheets (two, rotatable)	Polarization of light	Students understand how filter orientation affects light transmission	Rotating one filter over another, observing changes in brightness	Why does rotating one filter make the light darker, then bright again?	IB PYP Grade 3 — "How the World Works": technology & innovation
Bar magnet and coil/compass set	Magnetic fields and electromagnetism	Students understand magnetic interaction and simple induction	Moving the magnet near the compass/coil, observing the compass needle move	What makes the compass needle move without being touched?	IB PYP Grade 3 — "How the World Works": technology & innovation
Battery and simple circuit components	Electrical current and circuits	Students understand the basic components of a closed circuit	Assembling a battery–wire–bulb circuit until it lights up	What happens if one of the wire connections is removed?	IB PYP Grade 3 — "How the World Works": technology & innovation

Table 2. Shared demonstration toolkit: physics concepts framing at primary level framing at high school level Jaya Plus Montessori School

Tool	Physics Concept	Learning Objective	Student Activity	Guiding Question	Curriculum Alignment
Solar panel wired to an LED lamp	Conversion of light energy into electrical energy	Students understand the relevance of renewable energy for sustaining healthcare services in remote settings	Operating the solar panel, discussed in the context of healthcare facilities without stable electricity access	How could a solution like this help a clinic without access to stable electricity?	High school physics curriculum — energy & sustainability (application, not diagnostic/therapeutic)
Polarizing filter sheets (two, rotatable)	Polarization of light	Students understand the physics principle behind polarization-based optical diagnostic instruments	Rotating the filters, connecting the observation to optical diagnostic instruments	How is this polarization principle used in medical diagnostic instruments?	High school physics curriculum — waves & optics; medical physics application
Bar magnet and coil/compass set	Magnetic fields and electromagnetism	Students understand the physical basis of the strong magnetic fields used in MRI machines	Moving the magnet near the compass/coil, linked to the operating principle of MRI magnets	How does this simple magnet principle relate to how an MRI machine works?	High school physics curriculum — magnetism; medical physics application (radiology/MRI)
Battery and simple circuit components	Electrical current and circuits	Students understand how electrical circuits underlie diagnostic/imaging medical equipment	Assembling a simple circuit, linked to the electrical systems in medical imaging devices	How is this circuit principle applied in medical imaging equipment?	High school physics curriculum — electricity; medical physics application

The solar panel demonstration represents an application of energy technology in a healthcare context (e.g., powering medical devices in off-grid facilities; Franco et al., 2017), rather than a core medical physics principle underlying diagnosis or treatment — unlike the polarizing filter, magnet/coil, and circuit demonstrations, which map directly onto diagnostic and imaging technologies used in medical physics.

Procedure at Primary level

Aligned with the IB PYP transdisciplinary theme "How the World Works," the session was delivered as an interactive presentation combined with guided, hands-on exploration of each tool (Hofstein & Lunetta, 2004). Students were invited to operate the solar panel and observe the lamp turning on, rotate the polarizing filters to observe changes in light transmission, and handle the magnet and compass to observe magnetic interaction. Facilitators guided discussion toward the Grade 3 focus (technology and innovation solving everyday problems) and the Grade 4 focus (renewable and sustainable energy), using the tools as concrete anchors for these themes.

Procedure at High School level

The same set of tools was used in a workshop combining a scientific talk on medical physics applications (radiology, medical imaging, and radiation therapy), a discussion of medical physics career pathways, and a guest session from BRIN on quantum physics and material science. During the hands on segment, students engaged with the identical tools used at the primary level, but the facilitators explicitly connected each demonstration to its medical physics application, as detailed in Table 1-2 for example, linking the magnet-and-coil demonstration to the operating principle of MRI magnets (McRobbie et al., 2017), and the polarizing filters to polarization-based optical diagnostic tools (Ghosh & Vitkin, 2011).

Evaluation

To assess the impact of the workshop at Jaya Plus Montessori School, a pre-test was administered before the session to measure students' baseline knowledge of physics concepts and their applications in medicine, followed by a post test covering the same core concepts after the session (Dimitrov & Rumrill, 2003). Comparing pre and post test results allowed the team to evaluate gains in student understanding and interest attributable to the workshop.

3. Results and Discussion

Implementation of the activity

The medical physics workshop for high school students at Jaya Plus Montessori School and the energy and technology session for primary students at Genesis Global Community School were carried out on 14 July 2026 and 30 January 2026, respectively, following the procedures described in Section 2. Students at both schools participated in the scientific talks and hands-on demonstrations, engaging directly with the solar panel, polarizing filters, magnet and coil set, and battery circuit components described in Table 1 and 2 (Figures 2 and 3).

Facilitators recorded informal, qualitative observations during the hands-on segments, noting that students asked follow-up questions connecting each demonstration to real-world technologies renewable energy systems at the primary level, and medical imaging and diagnostic equipment at the high school level. No formal engagement instrument (e.g., an observation rubric or structured participation count) was used to systematically measure engagement; these observations therefore reflect the facilitators' unstructured impressions rather than a validated measure, and are reported here as such rather than as quantified evidence of engagement level. We do not interpret this participation and question-asking, by itself, as evidence of learning gains; the more direct evidence for learning gains at the high school level comes from the pre-test and post-test results reported in Section 3.2, which we treat as the primary quantitative indicator of the workshop's impact on student understanding



Figure 2. Primary students at Genesis Global Community School engaging with the demonstration tools during the workshop.



Figure 3. High school students at Jaya Plus Montessori School engaging with the demonstration tools during the workshop.

Pre-test and post-test results

To evaluate the impact of the workshop on student understanding, a pre-test and post-test were administered to high school students at Jaya Plus Montessori School,

covering core concepts in medical physics and its applications. The results are summarized in Table 3 and illustrated in Figure 4.

Table 3. Pre-test and post-test results of high school students at Jaya Plus Montessori School.

	Pre-test (%)	Post-test (%)
Mean	69.9	82.5
SD	21.31	14.79

As shown in Table 3, the class average increased from 69.9% on the pre-test to 82.5% on the post-test, an improvement of 12.6 percentage points, while the standard deviation decreased from 21.31 to 14.79. As individual-level pre- and post-test scores were not retained for this cohort, we were unable to conduct an inferential statistical test (e.g., a paired-samples t-test) to determine whether this improvement was statistically significant; this descriptive improvement should therefore not be interpreted as confirmed statistical significance. We note this as a limitation of the current evaluation (see Section 5) and recommend that future iterations of this program retain individual-level data to enable such analysis (Dimitrov & Rumrill, 2003).

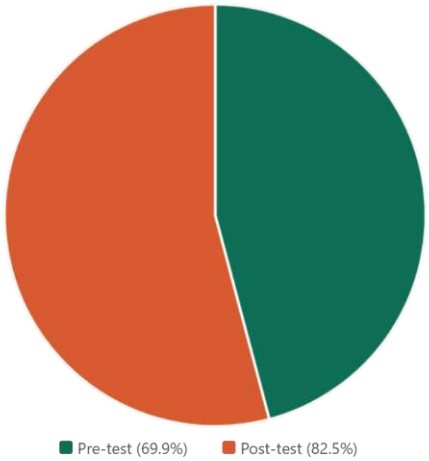


Figure 4. Average pre-test (69.9%) and post-test (82.5%) scores of high school students at Jaya Plus Montessori School, showing an overall improvement following the workshop.

4. Conclusion

This community service program set out to demonstrate that physics becomes more relevant and engaging when connected to real-world applications, using a shared demonstration toolkit solar panel, polarizing filters, magnet and coil set, and battery circuit components reframed for two age groups: a medical physics workshop for high school students at Jaya Plus Montessori School, and an energy and technology session for primary students at Genesis Global Community School. Descriptive pre- and post-test results at the high school level (69.9% to 82.5%, with reduced score variability from SD 21.31 to 14.79) suggest that the workshop supported gains in student understanding, consistent with this objective.

This descriptive improvement should not be interpreted as confirmed statistical significance, and the absence of a control group, individual-level data for inferential

testing, and primary-level assessment limits how strongly these gains can be attributed to the intervention alone. Nonetheless, the program's dual-audience, single-toolkit approach illustrates a feasible, resource-efficient model for extending physics outreach across educational levels one that future iterations can strengthen through more rigorous evaluation, comparison groups, and longer-term follow-up on students' interest and career awareness.

Several limitations should be noted. The evaluation relied on a single high school cohort with no control group, limiting the ability to attribute score gains solely to the intervention rather than other factors. As individual-level pre- and post-test scores were not retained for this cohort, we were unable to conduct an inferential statistical test (e.g., a paired-samples t-test) to determine whether the observed improvement was statistically significant; this descriptive improvement should therefore not be interpreted as confirmed statistical significance. Pre- and post-testing was conducted only at the high school level, so the impact of the primary-level session on student understanding was not formally measured. In addition, two items (Questions 6 and 8) showed a slight decline from pre-test to post-test, indicating that not all concepts were reinforced equally well by the current demonstration format. Facilitators' observations of student engagement during the hands-on segments were informal and qualitative, without a structured observation rubric or participation count, and should be read as such rather than as a validated measure of learning. Finally, the assessment captured only short-term knowledge gains, without follow-up data on whether the workshop influenced students' longer-term interest in physics or their consideration of medical physics as a career path.

Future iterations of this program should retain individual-level pre- and post-test data to enable inferential statistical analysis, extend evaluation to the primary level, and incorporate a comparison group where feasible. Revisiting the demonstration approach for the topics behind Questions 6 and 8 may help address the weaker gains observed for those concepts, and adopting a structured engagement measure (e.g., an observation rubric or participation count) would strengthen future claims about student engagement. Following up with participating students over time would help assess longer-term shifts in interest and career awareness (Tai et al., 2006). Expanding the program to additional partner schools would further test the scalability of the shared-toolkit model, building on our prior work introducing medical physics to high school students (Sinaga et al., 2026; Budiman et al., 2025), and would strengthen its contribution to Indonesia's broader effort to build a stronger pipeline of students informed about and interested in medical physics and applied science careers.

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